V. TECHNOLOGY OPTIONS AND ANALYSES

A. Discussion of Technologies

The agency knows of a variety of technologies that could be implemented by the manufacturers to meet the various proposed tests. This section discusses those technologies. Based on discussions with vehicle manufacturers, the agency believes many of the technologies could and will be used to meet the variety of tests.

The performance requirements of FMVSS 208 already provide considerable design flexibility for manufacturers. The standard's occupant requirements are performance requirements and do not specify the design of an air bag. Instead, vehicles must meet specific injury criteria performance limits (ICPL) measured on test dummies during barrier crash tests, for example at speeds up to and including 30 mph at any angle up to 30 degrees in either direction from perpendicular, or meet the ICPL in an alternative generic sled test.

While the current and proposed standard requires air bags to provide protection for properly positioned occupants (belted and unbelted) in relatively severe crashes, and air bags must deploy quickly to provide such protection, the standard does not require the same speed of deployment in the presence of out-of-position occupants, or even any deployment at all. The standard allows for the use of dual or multiple level inflator systems and automatic cut-off devices for out-of-position occupants and rear facing infant restraints. The agency notes that dual level inflator systems can provide the equivalent of a softer air bag for lower speed crashes and/or when occupants are close to the air bag or are belted, and a faster, more powerful air bag to provide protection in severe crashes and/or in crashes with unbelted occupants. The agency also notes that FMVSS 208 does not specify a crash threshold at which air bags must deploy, and that thresholds could be raised substantially for most current vehicles while still meeting the requirements of FMVSS 208. Injury protection at lower speeds can be and has been accomplished with a softer, compliant interior design.

B. Out-of-Position Test Technologies

There are essentially two ways to meet the out-of-position tests: **suppression** of the air bag (the air bag is turned off), or a **low risk deployment** of the air bag (dummy test results meet the injury criteria when the air bag is deployed with the dummy on or close to the air bag).

1. Suppression of the Air Bag

Using information supplied by various sensors inside the vehicle, a determination would be made by the vehicle s computer controlled occupant protection system that the air bag should not deploy.

2. Low Risk Deployment

Low risk deployment of the air bag might be accomplished either by having a single-stage air bag system that is designed to not injure out-of-position occupants or by having two or more stages of air bag deployment. In a dual-stage or multi-stage system, the lowest level of deployment would be a low risk deployment, while higher levels of deployment would be used when the occupant needs more protection. The agency has tested driver air bags that can meet the low risk deployment criteria as a single-stage air bag (4 of 11 MY 98/99 vehicles and 1 of 4 pre-MY 98 vehicles tested met the proposed criteria). On the passenger side, only 1 of 14 vehicle tests met the 6 year old criteria. This vehicle was the only one tested with a dual-stage air bag and it passed the out-of-position tests at the lower level deployment of a dual-stage air bag. This vehicle was not tested using the 3 year old dummy.

It would appear that meeting the injury criteria on the driver side will be easier than meeting the injury criteria on the passenger side using low risk deployment air bags. There are several reasons for this: 1) The current driver side air bags are not as aggressive as passenger side air bags. The driver is usually directly behind the steering column and there is less distance from the steering wheel to the driver than from the instrument panel to the right front passenger. Thus, the air bag for the driver side is smaller and needs less energy to inflate than the right front passenger bag. There is also the possibility of recessing the air bag back from the plane of the steering wheel, allowing it to start to open before contacting the driver. 2) A small child is not as tolerable to injury as an adult, thus the ICPLs are lower on the small dummies (e.g., the 3 year old dummy) than on the 5th percentile female dummy used in the driver position.

Sensor Technologies

The sensor technologies being investigated to supply information to the computer logic to determine when and how severely to inflate air bags can be divided into the following categories:

1) crash severity sensors

2) occupant weight sensors

3) occupant proximity and motion sensors

4) safety belt use status sensors

5) seat position sensors

3. Crash Severity Sensors

Two general types of crash severity sensors are in use today. The design goal is to make an early determination of the crash forces transmitted to the occupant compartment, while ignoring forces that will not require air bag deployment. The recent trend is towards a system with a single point crash sensor, an electronic accelerometer located in or around the passenger compartment.

The second type of system is the more expensive multi-point sensing system. In this system, electromechanical switches are used in combinations of discriminating sensors and secondary sensors located at different points in the forward part of the vehicle. The discriminating sensors located in the front crush zone activate at a specified change in velocity, while the secondary sensor located further back are used to prevent unwanted air bag deployments from localized damage. Several years ago, most models had multi-point sensing systems. Whether a vehicle needs a multi-point sensing system or can use a single point crash sensor system depends on a variety of factors, including the vehicle crush characteristics over a wide range of crash pulses.

The offset deformable fixed barrier test may force some manufacturers into using a multi-point sensing system. This system may include a combination of electronic (single point compartment sensors) and electromechanical (crush zone) sensors. Multi-point sensing may be necessary for dual-level inflation in order to get more information about the speed of the collision.

Current air bag systems use the output from the crash severity sensors to determine when to deploy and when not to deploy the air bag. Most systems are set to have a no-fire zone at 8 mph or less and to have an all-fire zone with a change in velocity (delta V) of 15 mph or more. This decision speed is called a threshold. Some manufacturers currently are using different thresholds for unbelted and belted occupants. A higher threshold is used for belted occupants (all fire at 18 mph or higher), since belted occupants are at a lower risk of injury. One of the possible technologies for meeting the up to 25 mph offset test, which has a belted occupant, would be to raise the air bag deployment threshold to have no deployment in this long duration crash pulse test. To make this decision, the manufacturers would attempt to determine the risk of injury at different speeds with and without the air bag for belted and unbelted occupants in particular make/models. The agency has crash tested one vehicle (Chevrolet S-10 pickup) <u>with no air bag</u> at 15 mph and found that the unbelted 3-year-old passenger dummy did not pass the neck criteria. It is not known whether other passive interior changes, such as adding padding, could be used to lower injury risk for unrestrained occupants if the air bag firing threshold were raised.

Designers must consider how a change in the sensors would affect the timing of deployments for higher speed crashes, before raising the lower threshold. Some manufacturers have already increased their deployment thresholds, particularly in other countries that have very high belt usage. A high threshold may be easier to accomplish in particular vehicles because of their design and crash pulse than in other vehicles.

4. Occupant Weight and Pattern Recognition Sensors

The purpose of a weight sensor is to measure the size of an occupant by measuring forces on the seat. Some systems also measure the distribution of the occupant on the seat to improve the ability to classify occupants and their location on the seat. Recent technology developments include measuring the pattern of pressure distribution on the seat or deflection of the seat and using this pattern to identify whether there is a child restraint on the seat, the size of the occupant, and whether the occupant is sitting back in the seat or up on the front edge.

Three types of weight sensors are being developed. The first uses resistive strain gauges or load cells, typically near the base of the seat, which indirectly lead to a measurement of weight. The agency does not have a cost estimate for these systems, and is not sure how they could work for a bench seat, but it is believed that they could be less costly than the mat type system for a bucket seat. The second type is a bladder type system within the seat cushion that measures pressure. However, neither of these systems have received as much attention as the mat-type electronic pressure sensor system because they cannot provide as much information about the occupant as the pattern recognition technology being developed.

The third type of system is a weight sensing electronic mat. The electronic mat, which is installed in the seat cushion, is an array of conductive polymeric sensors which change resistance under load. The initial Mercedes-Benz mat was designed to deactivate the air bag when the seat was empty or had a low weight in it. The nominal deactivation threshold was 26 pounds.

The heaviest child dummy in the proposal is the 6 year-old, that weighs about 54 pounds with all the instrumentation. Thus, the proposal could be met by a weight sensor that distinguishes between the 6 year-old dummy and a 5th percentile female dummy at 107.8 pounds.

5. Occupant Presence, Proximity, and Motion Sensors

A wide variety of sensing technologies have been explored by suppliers and manufacturers to detect occupant presence, proximity, and in the case of child restraints, seat position. Technologies being investigated include passive and active infrared, superaural acoustic, capacitive (electric field), radar, and visible imaging. A passenger side system could statically make a determination of a RFCSS, a 3 year old dummy, and a 6 year old dummy where the air bag should be turned off and distinguish these occupants from a 5th percentile female dummy where the air bag should be on. In general, the suppliers and manufacturers are working towards a dynamic system updating information every 10 ms or so to make decisions. A dynamic system theoretically can determine that an occupant has moved too close to the air bag (out-of-position), either through pre-impact braking or the movement caused by more minor initial impacts in a multiple impact crash, and is quick enough to turn off the air bag or determine that a low-risk deployment is appropriate. Static detection systems are reportedly going to be used if dynamic systems are not developed in time. However, it is more likely that these more expensive systems with occupant presence and proximity sensing will be used as part of a dynamic system in the future. It may well be that two types of systems may be used in conjunction with each other to eliminate to the extent possible the potential for false readings.

Capacitive (Electric Field): This technology senses the dielectric loading of an oscillating electric field set up between sets of electrodes. An electrical field can be used to measure an array of displacement currents. Fixed electrodes can all be installed in the seat cushion or seat back, or they can be installed in the seat and the instrument panel and headliner, each of which can generate an electric field and measure the loading currents out of the electrode and the received currents from the other electrodes. When a person is in the seat, the person screens the electric field because of the body s high internal conductivity, and thereby shunts the displacement current to other receiving electrodes and to the automobile ground return. The electrical characteristics are then interpreted to determine the presence and size of the occupant in the seat. This type of system is currently in production.

Passive Infrared Systems: These systems depend on the detection of infrared emission from the skin and face of occupants. The amount of energy emitted is proportional to the 4th power of its absolute temperature. A coarse resolution optical system is required to focus the seat environment onto an infrared sensing array. Infrared emissions must be correlated with conditions of occupancy. Care must be taken so that the system is not fooled by blankets, which are sometimes thrown completely over infants in rear-facing child seats. Infrared emissions overload can come from cigarettes, heat soaked vehicle interiors, hot food and beverages and sunlight. These occurrences must be designed around or a second type of sensing system must be used to assure no false readings.

Ultrasonic Sensing, Non-imaging Pattern Recognition: These systems use a broad beam of pulsed ultrasonic waves to illuminate the air bag deployment zone and the seat occupancy zone. These systems attempt to recognize when a seat is unoccupied or the location of the occupant, adult or child, whether still or moving towards the instrument panel. The principle of ultrasonics is based on sonar technology, pulsing a brief, inaudible signal, timing its return, and calculating the distance. Multiple transducers may be placed in the instrument panel, overhead console and trim around the A-pillar, B-pillar or side roof rail. Multiple transducers can be used to obtain the optimal line of sight to the areas of interest, and to recognize and track the movement of the occupant. The ultrasonic system has been designed based on priority inputs and time compression
within close target proximity to adequately capture the fact that unrestrained occupants may start into a crash normally seated but, due to precrash braking or slow onset types of crashes, may be just moving into close proximity to the instrument panel at the time of the firing command.

Ranging Systems: These systems rely on bouncing a beam of waves off an object and measuring their transit time from source to target to detector. The wave beam may be acoustic, optical, infrared or radar. Ranging systems can be used to measure proximity of objects to the air bag. The beams are usually narrow, less than 10 degrees and intercept a limited portion of the target.

Imaging Systems: These systems provide two-dimensional maps of some reflective feature of the vehicle interior. They may be visible optical or infrared. The two-dimensional images must be interpreted by a computer. An array of light and dark cells within the image must be correlated with hazardous and nonhazardous air bag deployment conditions.

The most advanced systems combine more than one type of sensing system in an attempt to provide reliable occupant detection for a wide variety of occupant types in a wide variety of real world conditions continuously updating dynamically (very close to real time).

6. Safety Belt Use Sensors

The driver side already has a restraint-use sensor to activate the warning light and buzzer if the driver is not using the safety belt. While some vehicles have a passenger side restraint use sensor, they are not required. Some manufacturers are installing more reliable safety belt use sensors, moving from a mechanical to a non-mechanical system (known as the Hall effect).

7. Seat Position Sensor

Seat position sensors can provide an indication of the position of the driver or passenger. If the seat is pulled all the way forward, the occupant is positioned close to the air bag. They offer a surrogate for a more direct measurement of driver size (the driver seat pulled all the way forward likely indicates a small person). They are available and at least one manufacturer is planning to install them in the near term.

C. High Speed Test Technologies

1. Dual Stage or Multiple Level Inflator

The benefit of a dual stage or multiple level inflator may overlap in both the low risk deployment option and in the high speed tests. Dual stage or multiple level inflators contain two separate initiators and require a control module which can sequence the firing of the stages under the defined conditions. In other words, each stage can be ignited separately, just stage A or just stage B, both stages can be fired together (A and B simultaneously), or stage A can be fired and then stage B can be fired after a time delay. Whether one or two stages fire would be determined by sensor input and algorithms. Sensor input can take many forms; for example: the severity of the crash, the position of the occupant, the size or weight of the occupant, the belt use of the occupant, the seat position of the occupant, etc.

The addition of satellite crash severity sensors (described above) may be necessary to help with the estimation of crash severity for the multi-stage inflator, or may be added for the proposed offset test.

2. Structural Integrity Improvements

A high speed offset test, like the 35 mph (40%) offset test could cause some manufacturers to improve the structural integrity of the front of their vehicle, along with air bag changes.

Structure could be added in the wheel well area or in the firewall/floor pan area to improve test scores in the offset tests.

D. Analysis of Alternative High Speed Tests

Target Populations Related to High Speed Test Procedures

In Chapter II, the overall target populations for fatalities and injuries and for out-of-position occupants were estimated. In this section, we will relate the alternative high speed tests considered to target populations.

The objectives of the FMVSS 208 high speed test procedures are to provide crash simulations that are representative of real world crashes that have the potential for serious injury or fatality, and to test how well the vehicle and its restraint system protect outboard front seat occupants in those situations. One of NHTSA s objectives in this rulemaking is to determine what are the appropriate combination of tests to assure that air bags are designed to provide protection in the largest number of crashes causing serious injuries and fatalities, and at the same time to assure that unintended consequences (injuries caused by air bag deployment) are limited to the extent possible.

There were four types of high speed tests that were considered by the agency for this SNPRM:

1) Direct frontal barrier (like the current 30 mph rigid barrier test)
2) Oblique tests (like the current 30 degree angled, 30 mph rigid barrier test)

3) The current generic sled test

4) Offset tests (like the proposed Transport Canada 25 mph 40% offset deformable barrier test, the European offset deformable test and the unbelted offset test proposed by IIHS).

Major factors considered for these tests are:

1) The size of dummy to use in the test (5^{th} female, 50^{th} male, or both)

2) Whether the dummy is belted, unbelted, or both

3) The highest speed of the test and the range of speeds for the test (e.g., up to 30 mph, 18 to 30 mph)

4) Whether to run the oblique or offset tests on the left side (driver side) only or on both the left and right sides of the vehicle.

The types of crashes that could be covered by testing include:

1) a short duration, high deceleration crash pulse as is found in large numbers of potentially fatal crashes (represented best by a direct frontal barrier test),

2) a crash with the potential to generate occupant compartment intrusion to promote the design of structural integrity (an angled impact, represented best by an offset impact),

3) a crash which forces manufacturers to design air bags that are wide enough to provide protection in angled impacts (represented best by an oblique test and to some extent by an offset impact),

4) cover special circumstances like the (25 mph offset crash) that results in some air bag designs deploying very late in the crash sequence, which cause occupants to be out-of-position when the air bag deploys, and

5) provide an incentive to limit aggressivity to a second vehicle to the extent possible.

The major alternatives considered by the agency for the high speed tests for this SNPRM are:

1) A belted full frontal rigid barrier impact for 5th female and 50th male dummies Either at 30 mph or 35 mph.

2) Oblique belted tests (left and right side up to 30 degrees) at 30 mph or 35 mph

3) An unbelted full frontal rigid barrier impact for 5th female and 50th male dummies Either at 25 mph or 30 mph.

4) Oblique unbelted tests (left and right side up to 30 degrees) at 25 mph or 30 mph

5) Unbelted 40% offset tests (left and right side) at 30 or 35 mph

6) Belted 40% offset test (left side) at 25 mph

7) Belted 40% offset test (left and right side) at 35 and 40 mph.

8) Unbelted generic sled test at 30 mph

In order for the high speed offset tests to have a significant influence on structural integrity to reduce intrusion, the agency would have to consider proposing lower leg injury measurements and injury criteria, such as the Tibia Index.

In the NPRM, a NHTSA research paper examined eight particular alternative FMVSS 208 test procedures. For a discussion of these test procedures the reader is referred to a NHTSA research paper placed in the docket entitled Review of Potential Test Procedures for FMVSS 208, June 1998".[1] Based on comments to the docket and another year of crash data, this paper has been

[1] Review of Potential Test Procedures for FMVSS No. 208, June 1998: Hollowell, W.T, Gabler, C., Summers, S., and Hackney, J. See Docket No. NHTSA-1998-4405-10.

updated and placed in the docket and is entitled Updated Review of Potential Test Procedures for FMVSS 208, September 1999 . The agency examined the number of drivers and magnitude of the injury population influenced by each test simulation, crash pulse stiffness, intrusion produced by the test procedure and test procedure lead time. Table V-1 presents a summary of that information.

For this table only drivers were considered, right front passengers were not included since there is not a large difference between the driver and passenger in crash types. The target populations and AIS 3+ injuries were projected from NASS data of vehicles with air bags. All target populations in Table V-1 were limited to delta V s of 30 mph (48 kmph). However, the agency is considering some tests at 25 mph, some at 30 mph and other tests at 35 mph. Thus, the target populations are lower at 25 mph and higher at 35 mph. The effect of the different speeds considered on target populations is provided in Table V-2.

NHTSA determined that crash simulations involving an offset moving deformable barrier (MDB) represent the largest number of drivers and serious injuries, do a good job of representing real world crashes and would probably have a positive effect for compatibility. The vehicle-to-MDB tests have the desired stiff crash pulse, with considerable intrusion properties. Unfortunately, the agency believes the vehicle-to-MDB test procedure is a longer term (2-3 years) research and development activity beyond the time frame of the subject advanced air bag rule.

Table V-1
Alternative FMVSS 208 High Speed Crash Simulations Considered

	Test Procedure	Exposed Driver Population*	MAIS-3+ Driver Population	Crash Pulse/ Intrusion	Lead Time
1.	Rigid Wall/Full Frontal	263,981	5,054	stiff / low (0 - 6")	Available Now
2.	Rigid Wall Full Frontal Oblique	378,670 (L+R)	8,875 (L+R)	soft /high (> 6")	Available Now
3.	Fixed Full Frontal Deformable Barrier	353,306	3,170	soft / low (0 - 6")	1-2 years
4.	IIHS/EU Offset Deformable Barrier	378,670 (L+R)	8,875 (L+R)	soft /high (> 6")	Available Now
5.	Vehicle-MDB Full Frontal	263,981	5,054	stiff /low (0 -6")	2-3 years
6.	Vehicle-MDB Offset Stiff	932,907 (L+R)	20,297 (L+R)	stiff /high (> 6")	2-3 years
7.	Vehicle-MDB Offset Soft	378,670 (L+R)	8,875 (L+R)	stiff /high (> 6")	2-3 years
8.	Generic Sled Test	299,911	1,396	soft / None	Available Now

* Drivers in crashes annually at < 30 mph delta V, estimated from NASS-CDS.

The full frontal rigid barrier test (#1) has a stiff crash pulse promoting the design of frontal structures that manage crash energy and improved occupant restraints. It is believed this procedure has a positive influence on vehicle compatibility. This procedure has a large MAIS-3+ driver target population, but has little, if any, intrusion affects. The oblique rigid wall frontal test (Test #2), currently a part of 208 and a high speed offset test like EU or IIHS (Test #4) are considered to have soft crash pulses. Preliminary data reviewed by NHTSA indicates good performing vehicles in the offset can have less aggressive vehicle characteristics.

Test #4 (offset test) results in more intrusion than Test #2 (oblique test); both have slightly larger driver MAIS-3+ target populations than Test #1. With the combination of full frontal and oblique or offset requirements, it is believed that to do well in both tests, a vehicle s structure must not be too stiff (e.g., that the occupant cage must be well designed and the vehicle frontal structure must be optimized for energy dissipation). The agency does not believe this combination of crash tests will adversely influence vehicle-to-vehicle compatibility.

The generic sled test did not promote any of the desirable qualities needed in a crash simulation. Similarly, the fixed full frontal deformable barrier (#3) did not provide the desired characteristics either.

Table V-2
Annual Driver Injury Estimates

	AIS 3+ Injuries*	Fatalities*
Generic Sled Test Unbelted	838	428
25 mph Frontal Unbelted	2,408	1,121
25 mph Oblique Unbelted	4,733	2,408
30 mph Frontal Unbelted	3,032	1,798
30 mph Oblique Unbelted	5,325	3,197
30 mph Offset Unbelted	5,325	3,197
35 mph Offset Unbelted	5,798	3,987
25 mph Offset Belted	3,156	1,140
30 mph Frontal Belted	2,022	852
30 mph Oblique Belted	3,550	1,514
35 mph Frontal Belted	2,118	1,125
35 mph Oblique Belted	3,720	2,000
35 mph Offset Belted	3,720	2,000
40 mph Offset Belted	3,838	2,463

* Target population estimates for drivers injured or killed at < listed delta V and crash type.

Because of the large number of tests to be considered, the agency rated the various tests according to a variety of factors and then considered combinations of tests to identify a set of tests which would promote the most effective air bag performance in the real world with the fewest number of tests. The following tables provide the agency s assessment of the various tests. The first three columns rate the tests by type; does the test have a soft or stiff crash pulse, will it result in more or less than 6 inches of intrusion for current vehicles, and is it a head-on or angled test. Next the agency rated on a scale of 0 to 5 whether the test would force manufacturers to make improvements in their vehicles.

0 - no effect on design for this factor

1 - small effect on design

3 - possible effect

5 - likely effect

For bag volume and depth the ratings are:

1 - small air bag

3 - medium size air bag

5 - large air bag

The factors considered included whether the test had an effect on crash sensing, structural improvement, multi-stage inflation, air bag volume depth and width and occupant sensing. These were all considered mutually exclusive for each test, with the exception that occupant sensing and multi-stage inflation are often times linked together.

The tests that drive likely improvements are the 25 mph (40%) offset test (proposed as belted) which will promote improvements in crash sensing and timing of the air bag. The 35 mph (40%) unbelted offset or the 40 mph (40%) belted offset test would promote improvements in structural integrity. The 5th female in the 30 mph unbelted frontal barrier test would promote designs toward improved occupant sensing and multi-stage inflation. The unbelted oblique test would promote wider air bags, with the offset test having some influence on the width of air bags. Finally, the unbelted 50th percentile male 30 mph unbelted frontal barrier crash test requires the deepest air bags.

Combinations of crash tests are provided on the table with one of the most notable tradeoffs occurring between the oblique tests and the high speed offset tests. The oblique test promotes wider air bags and the offset test promotes more structural integrity.

As will be seen later in this analysis, redesigned air bags have done well compared to the pre-MY 1998 air bags, however, NHTSA is proposing to delete the generic sled test as advanced air bags are phased in. The agency believes the generic sled test has limitations, such as: (1) the generic sled test is not a full-scale crash simulation, the test vehicle crush characteristics and crash pulse are not involved, no intrusion is possible, (2) the test vehicle crash sensors and associated computational hardware/software (algorithms) which make the air bag deployment decisions are not needed, (3) this test represents the lowest number of serious injuries of the eight tests considered in Table V-2, (4) the generic sled test does not do as well as other tests in representing a variety of real world crashes, and (5) the generic sled test is unrelated to vehicle-to-vehicle compatibility.

There are possibly trade-offs in design between meeting the at-risk out-of-position tests and at the same time meeting the high speed tests. Manufacturers could design their vehicles to the minimal performance required in the high speed test in an attempt to get the least aggressive air bag in the out-of-position tests. The agency believes it is possible to have separate design paths for the high speed and out-of-position tests. The target populations are much greater for the high speed tests than for the out-of-position tests. Thus, overall the greatest potential target population and the greatest potential benefit would be to require the strictest test regime for the high speed tests. This would require a high level of performance for air bags in the high speed tests and, at the same time, require the out-of-position test to be passed.

The two alternative high speed tests proposed by the agency attempt to achieve as many of the test properties desired as possible and limit the number of tests. Alternative 1 is shown as test combination 1, and Alternative 2 is shown as test combination 2 in Table V-5. The difference between the two tests depends upon the assumptions made. Specifically, it is assumed that the 30 mph frontal rigid barrier unbelted test including the 5th female dummy would likely force manufacturers into occupant sensing and multi-stage inflation for Alternative 1. In addition, Alternative 1 has an unbelted oblique test which pushes manufacturers toward wider air bags than the offset test of Alternative 2. On the other hand, the offset test in Alternative 2 would likely force manufacturers to improve structural integrity.

It should be noted that the agency has not tried to subjectively adjust the target populations in Table V-5 for overlaps in coverage (e.g., one could argue that the unbelted offset test will provide benefits in an unbelted frontal test also).

Table V-3
BELTED TESTS

	Crash Pulse		Intrusion		Occupant Kinematics		Driver Target Population		Improved Crash Sensing	Improved Structural Integrity	Requires Multi-Stage Inflation	Bag Volume Depth	Bag Volume Width	Required Occupant Sensing
	Soft	Stiff	< 6"	> 6"	Head-on	Angle	AIS 3+	Fatals						
30 mph Frontal Barrier		X	X		X		2,022	852						
50th									1	1	0	1	1	0
5th and 50th									1	1	0	1	1	0
35 mph Frontal Barrier		X	X		X		2,118	1,125						
50th									1	1	0	1	1	0
5th and 50th									1	1	0	1	1	0
30 mph Oblique (+/- 30 deg)	X			X		X	3,550	1,514						
50th									1	2	0	1	1	0
5th and 50th									1	2	0	1	1	0
25 mph Offset (40%)	X		X		X		3,156	1,140						
5th									5	1	0	1	1	0
35 mph Offset (40%)	X		X			X	3,720	2,000						
50th									5	4	0	1	1	0
5th and 50th									5	4	1	1	1	1
40 mph Offset (40%)	X			X		X	3,838	2,463						
50th									5	5	0	1	1	0
5th and 50th									5	5	1	1	1	1

Table V-4
UNBELTED TESTS

	Crash Pulse		Intrusion		Occupant Kinematics		Driver Target Population		Improved Crash Sensing	Improved Structural Integrity	Requires Multi-Stage Inflation	Bag Volume Depth	Bag Volume Width	Required Occupant Sensing
	Soft	Stiff	<6"	>6"	Head	Angle	AIS 3+	Fatals						
25 mph Frontal Barrier		X	X		X		2,408	1,121						
50th									1	1	0	2	1	0
5th and 50th									1	1	0	2	1	0
25 mph Oblique (30 degree)	X		X			X	4,733	2,408						
50th									1	1	0	1	5	0
5th and 50th									1	1	2	1	5	2
30 mph Frontal Barrier		X	X		X		3,032	1,798						
50th									1	1	0	5	1	0
5th and 50th									1	1	5	5	1	5
30 mph Oblique (+/- 30 degree)	X			X		X	5,325	3,197						
50th									1	2	0	1	5	0
5th and 50th									1	2	3	1	5	3
30 mph Offset (40%)	X		X		X?	X?	5,325	3,197						
50th									3	3	0	2	3	0
5th and 50th									3	3	1	2	3	1
35 mph Offset (40%)	X			X		X	5,798	3,987						
50th									3	5	0	3	3	0
5th and 50th									3	5	1	3	3	1
Generic Sled 30 mph	X		NA	NA	X		838	428	0	0	0	1	1	0

Table V-5
TEST COMBINATIONS

	Crash Pulse		Intrusion		Occupant Kinematics		Driver Target Populations		Improved Crash Sensing	Improved Structural Integrity	Requires Multi-Stage Inflation	Bag Volume Depth	Bag Volume Width	Requires Occupant Sensing	# 0f Tests
	Soft	Stiff	<6"	>6"	Head-on	Angle	AIS 3+	Fatals							
1 Up to 30 mph Frontal (B)		X	X		X		13,929	7,361	1	1	0	1	1	0	9
18-30 mph Frontal (U)		X	X		X				1	1	5	5	1	5	
5^{th} and 50^{th} all above															
+/- 30 Degree Oblique (B+U)50^{th}	X			X		X			1	2	3	1	5	3	
Up-25 mph Offset (B) 5^{th} L	X		X		X				5	1	0	1	1	0	
												Total Score #1 = 27			
2 Up to 30 mph Frontal (B)		X	X		X		11,370	6,353	1	1	0	1	1	0	9
22-35 mph Offset (U) L+R	X			X		X			5	5	1	3	3	1	
5^{th} and 50^{th} all above															
+/- 30 Degree Oblique (B) 50^{th}	X			X		X			1	2	0	1	1	0	
Up-25 mph Offset (B) 5^{th} L	X		X		X				5	1	0	1	1	0	
												Total Score #2 = 18			
3 Up to 30 mph Frontal (B)		X	X		X		12,319	5,521	1	1	0	1	1	0	9
18-25 mph Frontal (U)		X	X		X				1	1	0	2	1	0	
18-25 mph Oblique (U)L+R	X			X		X			1	2	3	1	5	3	
5^{th} and 50^{th} all above															
Up-25 mph Offset (B) 5^{th} L	X		X		X				5	1	0	1	1	0	
												Total Score #3 = 20			
4 Up to 30 mph Frontal (B)		X	X		X		14,008	7,777	1	1	0	1	1	0	9
18-30 mph Frontal (U)		X	X		X				1	1	5	5	1	5	
22-35 mph Offset (U) L+R	X			X		X			5	5	1	3	3	1	
5^{th} and 50^{th} all above															
Up-25 mph Offset (B) 5^{th} L	X		X		X				5	1	0	1	1	0	
												Total Score #4 = 28			

Table V-5 continued
TEST COMBINATIONS

	Crash Pulse		Intrusion		Occupant Kinematics		Driver Target Populations		Improved Crash Sensing	Improved Structural Integrity	Requires Multi-Stage Inflation	Bag Volume Depth	Bag Volume Width	Requires Occupant Sensing	# of Tests
	Soft	Stiff	<6"	>6"	Head-on	Angle	AIS 3+	Fatals							
5 Up to 30 mph Frontal (B)		X	X		X		6,015	2,489	1	1	0	1	1	0	5
Sled Test 30 mph (U)	X		NA		X				0	0	0	1	1	0	
5th and 50th all above															
Up-25 mph Offset (B) 5th L	X		X		X				5	1	0	1	1	0	
												Total Score #5 = 8			
6 Up to 30 mph Frontal (B)		X	X		X		10,852	6,637	1	1	0	1	1	0	8
18-30 mph Frontal (U)		X	X		X				1	1	5	5	1	5	
22-35 mph Offset (U) L+R	X			X		X			5	5	1	3	3	1	
5th and 50th all above															
												Total Score #6 = 28			
7 Up to 30 mph Frontal (B)		X	X		X		11,066	6,048	1	1	0	1	1	0	10
18-30 mph Offset (U) L+R	X		X		X?	X?			5	3	1	2	3	1	
Up to 35 mph Offset (B) L+R	X		X			X			5	4	1	1	1	1	
5th and 50th all above															
												Target Score #7 = 16			
8 Up to 35 mph Frontal (B)		X	X		X		12,979	6,654	1	1	0	1	1	0	13
Up to 35 mph Oblique (B) L+R	X			X		X			1	2	0	1	1	0	
18-25 mph Frontal (U)		X	X		X				1	1	0	2	1	0	
18-25 mph Oblique (U) L+R	X		X			X			1	1	2	1	5	2	
5th and 50th All Above															
Up-25 mph Offset (B) 5th L	X		X		X				5	1	0	1	1	0	
												Target Score #8 = 18			